THE THEORY OF RELATIVITY.

THE meeting of the Royal Society on February 5 was devoted to a discussion on the theory of relativity. It was opened by Mr. J. H. Jeans, who said it was a better analogy to liken the new principle, not to a key of the universe, but to a ward in its lock, which gave direction to the efforts made to open it, admitting some and excluding others. In this respect it resembled the doctrine of the conservation of energy and the second law of thermodynamics. Where any of these gave a positive result it was because a process of exhaustion showed that anything else would be impossible.

The foundation of the theory may be considered to have been laid by Einstein's hypothesis, put forward in 1905, that light from any source appears to any observer to travel with the same velocity C; this hypothesis was founded on the Michelson-Morley experiment, and has since been confirmed by that of Majorana; it also explains a number of physical phenomena. It can best be visualised by the idea that to each observer the wave-surface is spherical in the four-dimension continuum. Then $x^2+y^2+z^2+(iCt)^2$ (radius for the first observer) transforms into an identical expression with accented letters (radius for the second observer) by a rigid-body rotation. Such a rotation would resolve pure time into partly time, partly space, and *vice versa*. The following is an example of this: Suppose that a man lives seventy-five years, and dies 1000 miles from his birthplace; then to an observer on a rapidly receding star he might appear to have lived seventy-six years and travelled billions of miles. (In reply to Prof. Newall, who imagined paper screens to be erected at a distance of 100 light-seconds from the origin, from which a flash of light is emitted, and from which one of the observers moves while the other remains, Mr. Jeans admitted that the former would not see the reflections simultaneously, the reason being that the screens would not lie on a four-dimensional sphere to him.) This conception was preferable to that of the Lorentz contraction, which presented grave difficulties in the case of a rotating wheel, the axis of which is at rest in the æther; the rim would undergo contraction, while the spokes would remain unaltered.

Mr. Jeans used the following analogy to explain the nature of Einstein's latest theory. Imagine a race of men who had spent all their lives in caves. They would be in ignorance of the earth's rotation, and would consider gravity as a force constant in direction; however, two experiments might reveal the fact of rotation to them. If they set a ball swinging in an ellipse, by a long string, the apse of the ellipse would move; moreover, delicate measures would show that the course of rays of light was not quite straight relatively to their rotating framework. This is closely analogous to the observed progression of Mercury's perihelion and to the deflection of light-rays by the sun; in each case "we have tacitly assumed fixed axes where nothing is fixed: we have formed wrong ideas of the nature of gravitation, and our definition of a straight line is interwoven with the ideas of an untrue system of geometry."

The reason why the new law of gravitation cannot be put in simple form is that there is no *force* of gravitation; the laws of *motion* can be put in the simple form $\delta\int ds=0$. There are, however, two ways of defining *ds*. Einstein defines it as a line-element in a distorted space-time continuum. This necessarily involves the spectral shift to the red, and an objective curvature of space. It may also be simply defined as a conventional algebraical symbol given by Einstein's equation, but without assuming his physical interpretation; in this manner it is possible to deduce the two astronomical effects already verified, while leaving the shift of spectral lines undetermined. Decisive evidence for or against the spectral shift would be a guide as to the adoption of one or other definition of *ds*.

Prof. Eddington compared Euclidean space to a picture in a framework of rectangular coordinates, and Einstein's space to a map with curved lines of latitude and longitude. Just as the map could not accurately represent the earth's surface, unless it was made on a curved surface, so Euclidean space could not contain an accurate representation of the space-time continuum. We could look on Einstein's law of gravitation as giving instructions for the joining together of successive elements of space. The law must include all the laws of mechanics, including the conservation of energy and momentum.

Space and time could be explored in two ways—either by using clocks and measuring scales, or by observing moving particles and light-waves. The second method was both more elementary and more sensitive. An example of it was the search for the spectral shift. The reason for the shift might be briefly given thus. The time of vibration of a particle involves the factor $\left\{1-\frac{2m}{rC^2}\right\}^{-\frac{1}{2}}$ which clearly increases as r diminishes, so that the vibration is slower on the sun than on the earth.

Sir F. W. Dyson spoke on the motion of the perihelion of Mercury; the observed centennial motion exceeds that calculated on the Newtonian law by $43''$, which is much the largest unexplained quantity in planetary theory. Various attempts have been made to explain it. An excess of $\frac{1}{2}''$ of the sun's equatorial radius over the polar would suffice; this amount is considered to be in excess of what observation will admit; the latter suggests a slight excess of the polar radius; moreover, such an equatorial excess would produce a shift of the orbit-plane of Mercury too great to be admitted. An unknown planet is excluded, since it could not fail to have been seen or photographed at some of the total eclipses when such a body has been specially looked for. A ring of small planets would have to be in the plane of Mercury's orbit, or it would produce an effect on

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its node and inclination. This puts the zodiacal light out of court, even if its mass were sufficient, which seems unlikely. Prof. Asaph Hall suggested that the law of attraction should be modified, the index of r being taken, not as -2, but as $-2(1+d)$, where d is a small fraction, chosen empirically so as to fit the case of Mercury. This is the law adopted in Newcomb's tables, and therefore in the Nautical Almanac. It would give a centennial shift of the moon's perigee of $135''$. (The discussion of Dr. E. W. Brown seems to establish that there is no such excess of motion in the perigee, which discredits the Hall hypothesis.)

Einstein's theory perfectly explained the excess of motion of Mercury's perihelion, without introducing any arbitrary constant, or having any other perceptible effect on the planetary or lunar motions. By the method of exhaustion it seemed to hold the field. There remained a small excess of motion in the case of the node of Venus, but it was only 2½ times the probable error, and so was not unreasonable.

Prof. A. Fowler spoke on the attempts that had been made to detect the shift towards the red in the sun's spectral lines, and on the difficulties in the way, which arose from the effect of varying pressure, the rotation of the sun, and possible convection currents in its atmosphere. A series of cyanogen lines was selected for the test, as they were not subject to shift through pressure; care was necessary to choose isolated lines, as adjacent lines might influence the measures. The sun's rotation could be eliminated by observing opposite points of the limb. The results of the measures of Evershed, St. John, Schwarzschild, and recent Bonn observers were shown on the screen. The mean of all gave a shift towards the red of 0·003 Å. at the sun's centre and of 0·004 Å. at the limb, Einstein's predicted value being 0·008 Å. Prof. Fowler inclined to the view that the observed shift was due not to the Einstein effect, but to cooler descending convection currents at the sun's centre, and to the "limb effect" at the limb.

Mr. E. Cunningham gave the following example to show that the spectral shift need not necessarily occur on the equivalence hypothesis: Imagine two atoms each emitting light-vibrations in a non-gravitational field, the periods of vibration being the same. Referring them to a set of accelerating axes, we simulate a gravitational field. The synchronism between the two sets of waves is not destroyed; and on the equivalence hypothesis the relation of physical sequences in the simulated field is the same as in the real field. There is the qualification that the atoms must be free to fall—*i.e.* not constrained by neighbouring atoms; Mr. Cunningham doubted whether this was the case on the sun's surface. He went on to say that relativity did not necessarily imply the abandonment of the æther; a unique æther could be constructed on a mechanical basis; if it transmitted light, it must also transmit stress and energy.

Prof. A. F. Lindemann spoke of the observed average recession of 4 km./sec. in the B-stars; even those in the Orion nebula, which presumably were at rest relatively to it, showed this differential shift; he concluded that it was not a Doppler effect, and might be the Einstein one. He noted as a difficulty in the quantum theory of light that to an observer at rest the mass of a quantum would be infinite; moreover, he considered that since the mass of an electron changed with its speed, its period of vibration should also change. Speaking of Prof. Eddington's statement that a sphere of water of radius 500 million km. would fill all space, he preferred to say that to an observer on the sphere it would appear to do so, since all rays from it would be bent back to it by its attraction; but he thought there was nothing to prevent other space from existing outside it.

Prof. A. N. Whitehead showed a mathematical method by which Einstein's first two astronomical predictions might be satisfied without introducing time as the fourth dimension. The method left it uncertain whether the spectral shift would take place or not. Should the latter be finally proved not to exist, we might fall back on this method, which agreed with the facts at present observed.

A. C. D. CROMMELIN.

THE FLIGHT FROM CAIRO TO THE CAPE.

(1) AVIATION AND EXPLORATION.

THE enterprise of the *Times* in organising a flight from London to Cape Town *via* Cairo, Khartum, the Upper Nile, the interior of East Africa, Northern and Southern Rhodesia, and the Transvaal will certainly, if successful, greatly advance the theory and practice of travelling through the air from one distant part of the world to another.

The bearing of the whole question—air travel *versus* railway, ocean steamer, or road-motor transit—was well put a few days ago by Capt. Frederick Shelford in his address to the African Society. There is no real cause for rivalry or hostile competition between all four forms of rapid transport. Air travel by aeroplane or airship will for a long time to come be far more dangerous to life than road or rail transit, and a little more dangerous than sea voyages; but it will be very much quicker than all other methods. It will be impossibly expensive for the transport of goods or of many passengers. Sea travel by boat is the cheapest mode of conveyance; railways, on the whole, and especially in wild, little-developed countries, are as cheaply made as motor roads, and are much less expensive to maintain. For mails and for passengers in a great hurry, aeroplanes should have no rival, especially when meteorology is better understood, and when the great air routes of the world are duly provided with aerodromes at convenient distances.

It may seem to be stating too obvious a fact

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